



# *SHADOZ Highlights*

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SHADOZ Team

SHADOZ - Southern Hemisphere Additional Ozonesondes

*SHADOZ = A network of sub/tropical sites launching weekly  
balloon-borne Electrochemical Concentrations Cell (ECC)  
ozonesondes = <http://croc.gsfc.nasa.gov/shadoz>*

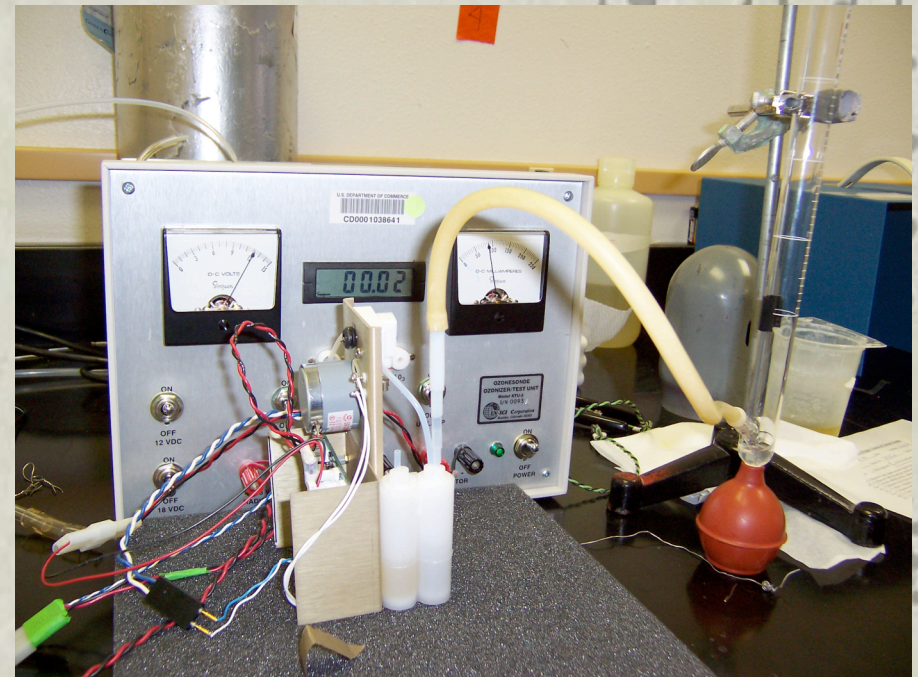
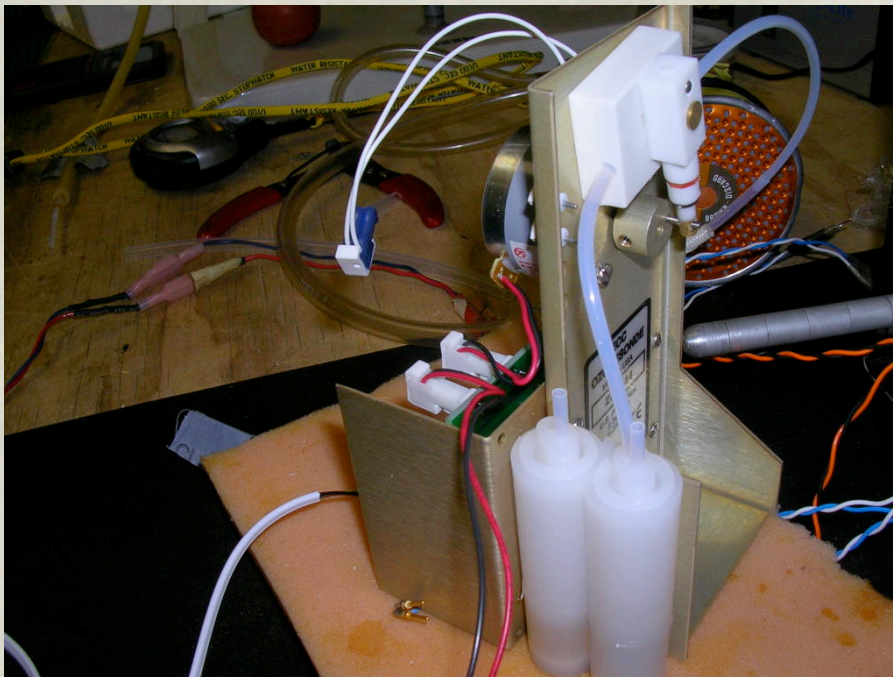


- ❖ 12 sites currently in operation
- ❖ 3 northern tropical sites: Alajuela (10N), Paramaribo (6N), Kuala Lumpur (3N)
  - Soon to add a northern subtropical site = Hilo, HI (19N, 155W)

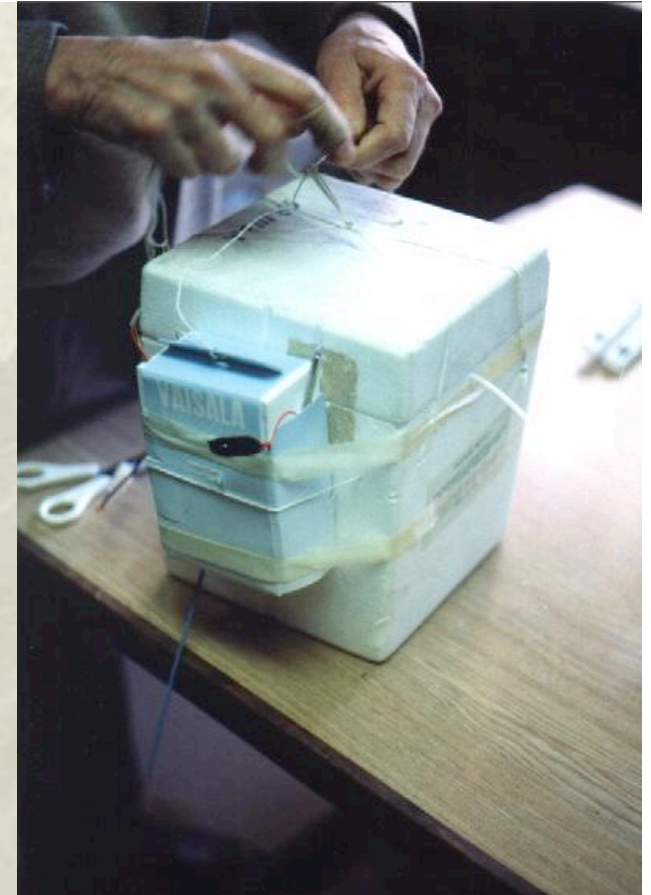
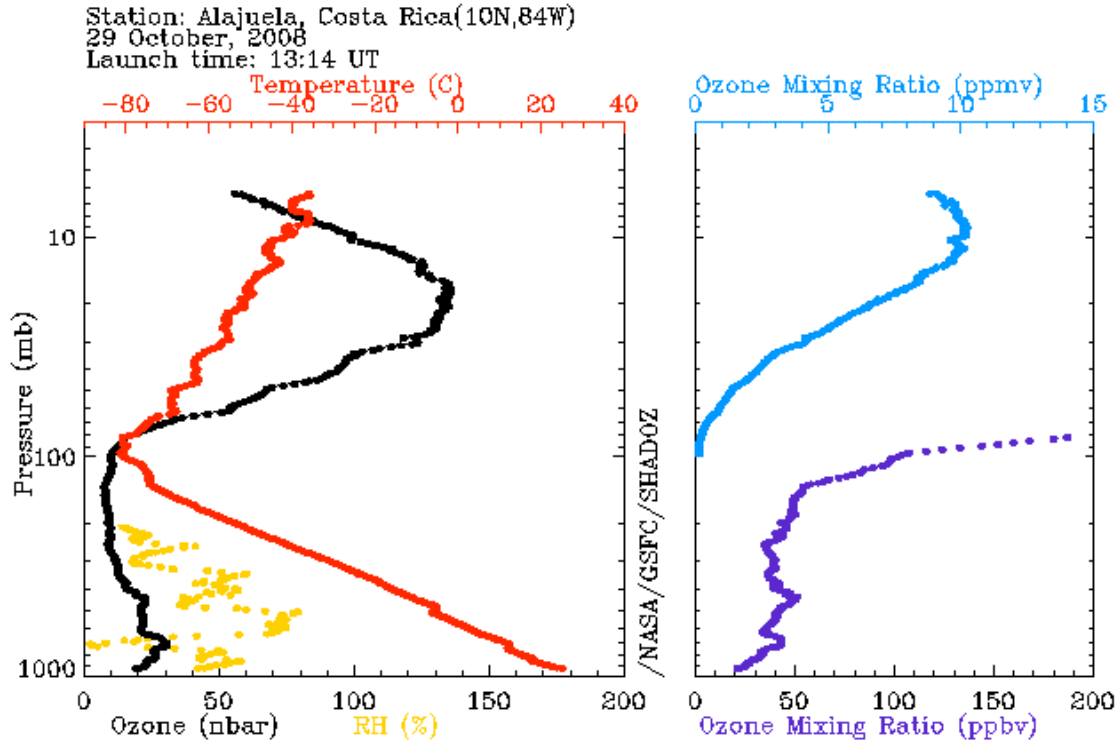
- ❖ 1-2 weekly launches with international sponsorship and support for infrastructure and supplies.

Current Participants	Affiliation	Country
Anne M Thompson - Principal Investigator	NASA/GSFC, Penn State	USA
Jacquie Witte	SSAI, NASA-GSFC	USA
Bertrand Calpini, G Levrat, R Stuebi	MeteoSwiss	Switzerland
Kok Kee Chow, leong Chow Peng	Malaysian Met. Service	Malaysia
Gert J R Coetzee, Danie Esterhuyse	South African Weather Service	South Africa
Masatomo Fujiwara	Hokkaido University	Japan
Ge Verver	Royal Dutch Met. Institute	Netherlands
William Ayoma	Kenyan Meteorology Dept.	Kenya
Neusa Paes Leme	Brazil Space Agency (INPE)	Brazil
Samuel J Oltmans, Holgar Vömel	NOAA/ESRL	USA
Jéssica Valverde	Universidad Nacional	Costa Rica
Françoise Posny	La Réunion University	France
Frank J Schmidlin	NASA/WFF	USA
Masato Shiotani	Kyoto University	Japan
Slamet Surayspriya	Indonesian Space Agency (LAPAN)	Indonesia
Seiichiro Yonemura	National Institute for Agro-Environmental Sc.	Japan

- ❖ Developed by Komhyr in the late 1960's - the ozonesonde consists of a pump and ozone sensing cells interfaced to a standard meteorological radiosonde.
- ❖ All of ozonesondes rely on the titration of ozone in a KI sensing solution according to the redox reaction:
  - $2\text{KI} + \text{O}_3 + \text{H}_2\text{O} \rightarrow \text{I}_2 + 2\text{KOH} + \text{O}_2$
- ❖ Ambient air is continuously forced into the sensing cell by a battery driven sampling pump. An electrical current is generated proportional to the mass flow rate of ozone through the cell. By knowing the volume flow rate and temperature, the electrical current can be converted to an ozone concentration:
  - $P(\text{O}_3) = R / (F \cdot 2) (I - I_0) T_{\text{air}} / (\text{flowrate}) P_{\text{cf}}$

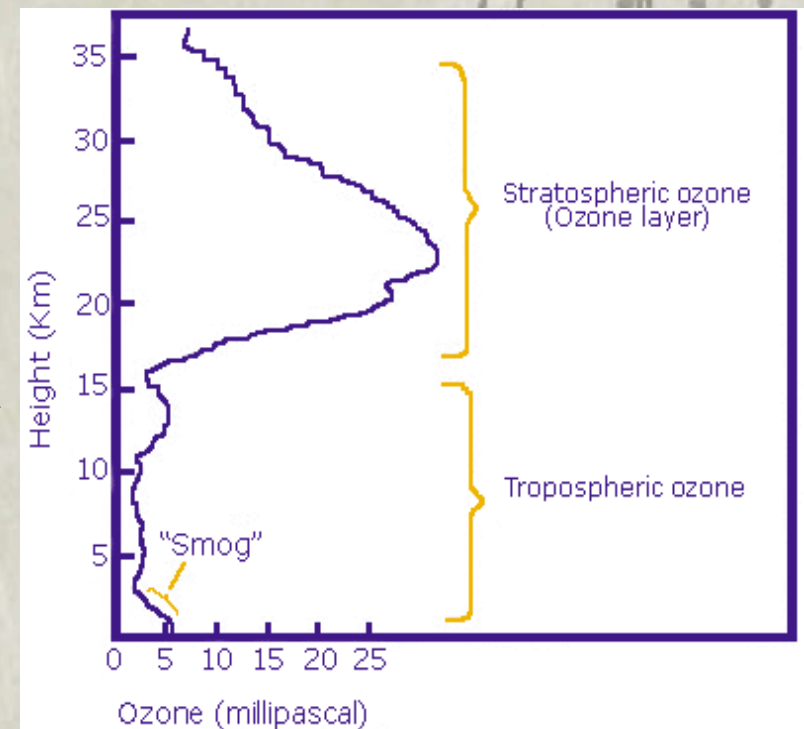


- ❖ Ozonesondes are designed as single-use instrument.
- ❖ Measured parameters = ozone concentration, ambient air pressure, temperature, humidity, and, in some cases, the wind direction and speed, and location.



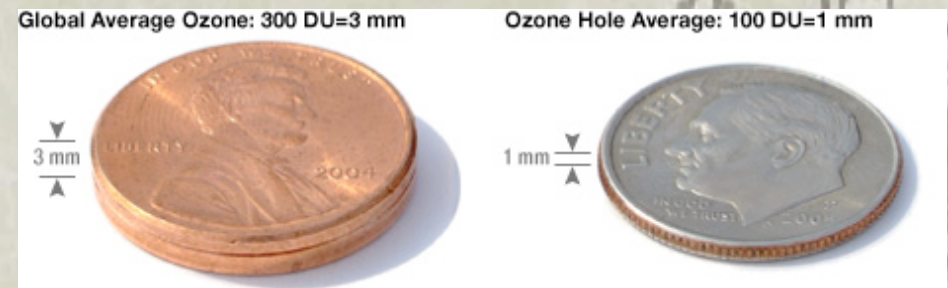
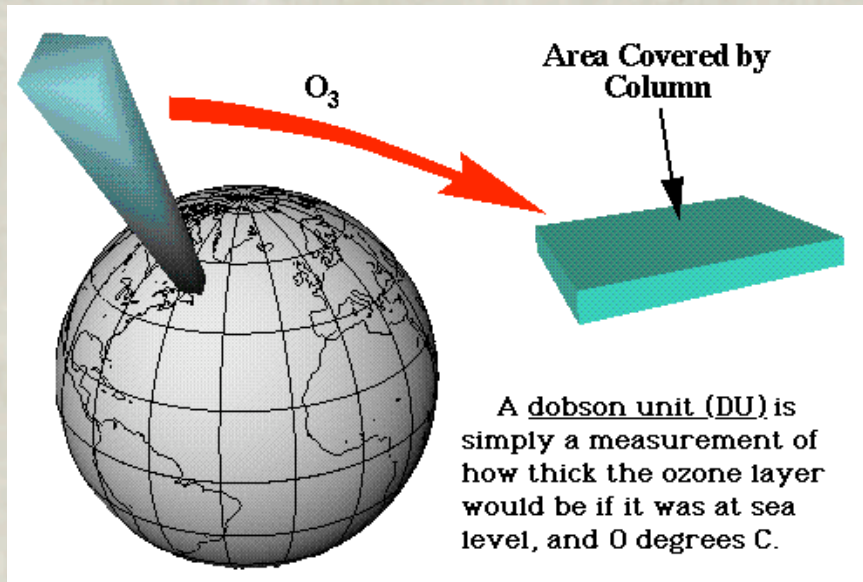
# *Tropospheric Ozone*

- ❖ Tropics is a large source of ozone
  - Strong human impact: biomass burning, development
- ❖ Chemical Cycles
  - Photochemical Source: Rx with UV and precursors - NO<sub>x</sub>, CO, VOC
  - Photochemical Sink - Reaction with OH
- ❖ Climate Link
  - Tropospheric ozone, a greenhouse gas, contributes significantly to recent, projected warming [Hansen et al, 2002]
  - Key ingredient in urban smog



# Dobson Unit

- ❖ The "Dobson unit" indicates how much ozone there is in the air above a certain point on Earth.
- ❖ a column of air with an ozone concentration of 1 Dobson Unit would contain about  $2.69 \times 10^{16}$  ozone molecules per  $\text{cm}^2$  at the base of the column.



<http://ozonewatch.gsfc.nasa.gov>

Data and images are publicly available:  
<http://croc.gsfc.nasa.gov/shadoz>

PS - Also on  
the Science  
System



# *Uses of the data*

## ❖ Tropical Characterization

### – Variability

- Interannual
- Regional
- Zonal, e.g. Wave-one

### – Ozone QBO

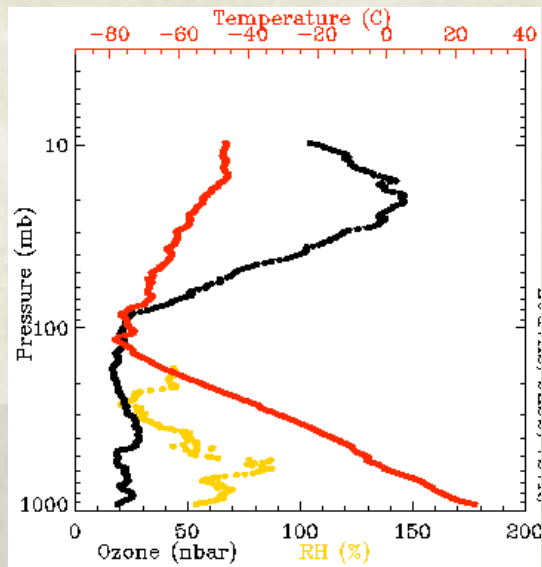
### – ENSO Event 1997/98

## ❖ Satellite Comparisons

<http://croc.gsfc.nasa.gov/shadoz>

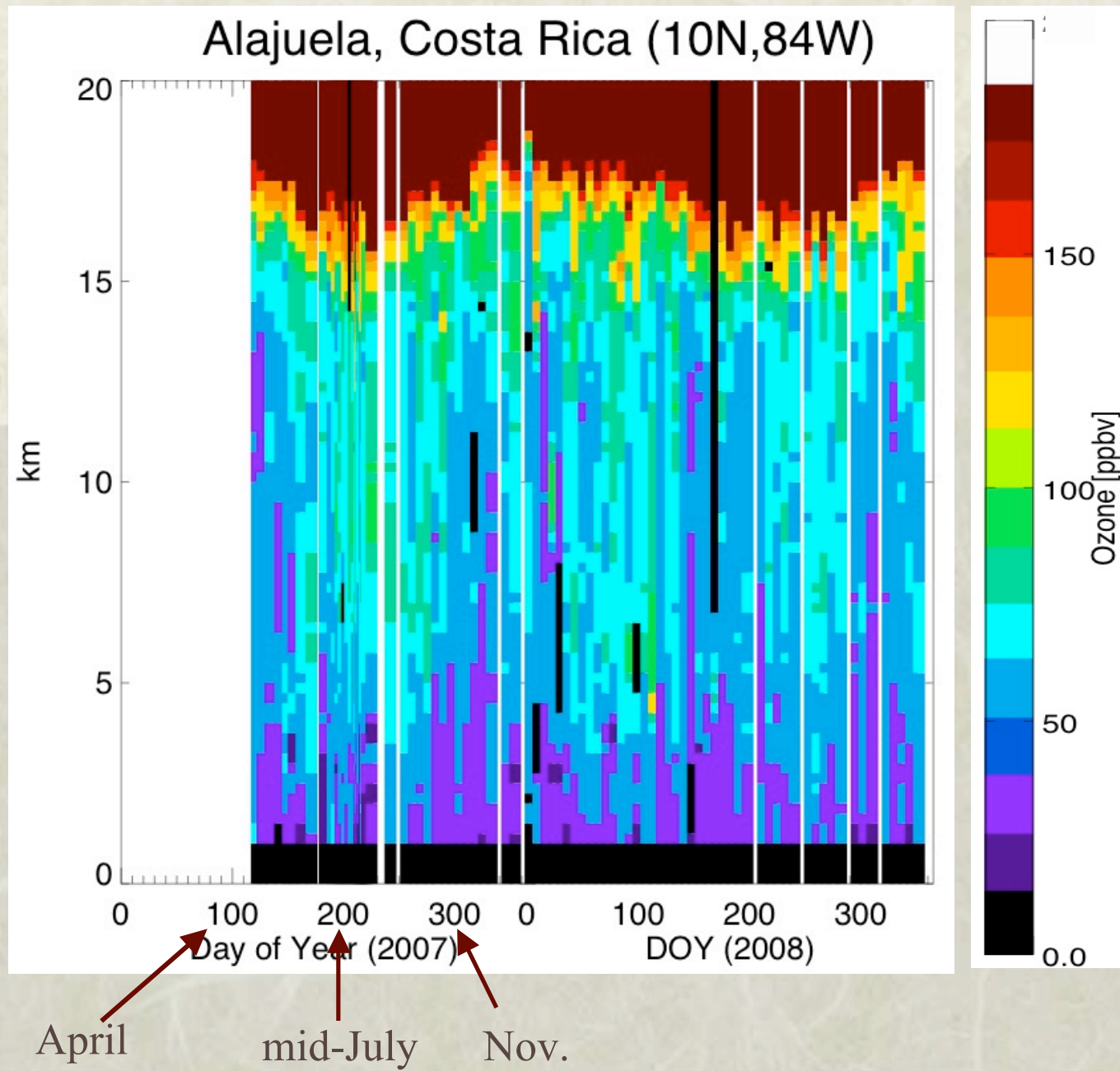


# *Interannual Variability*

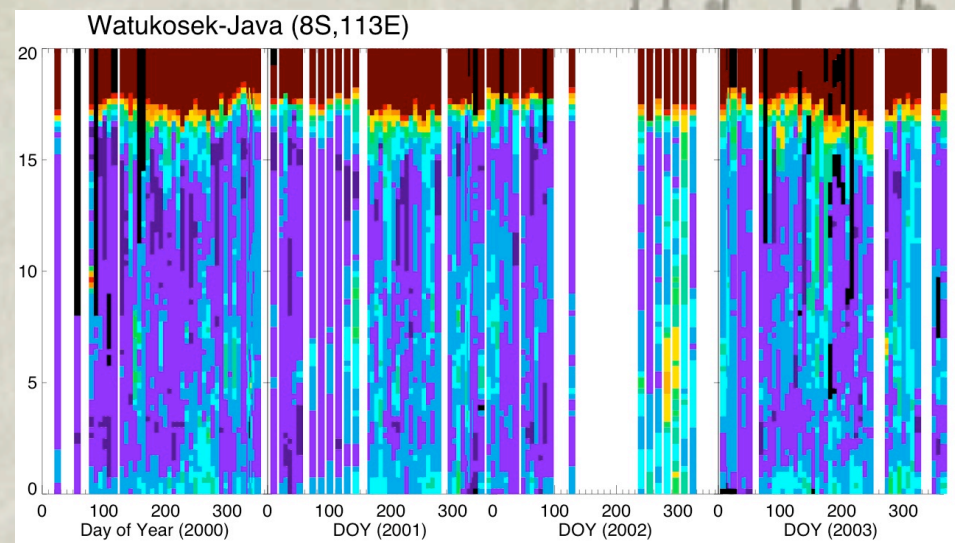
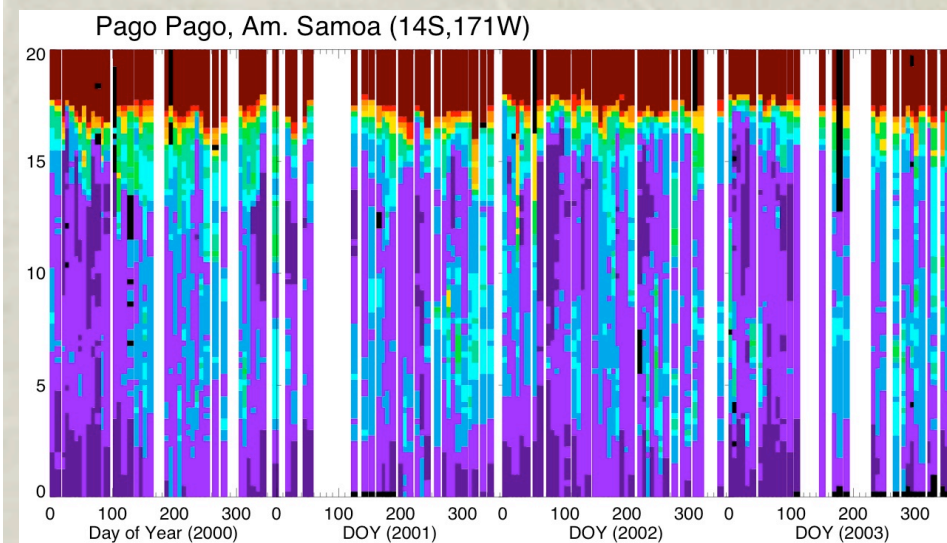
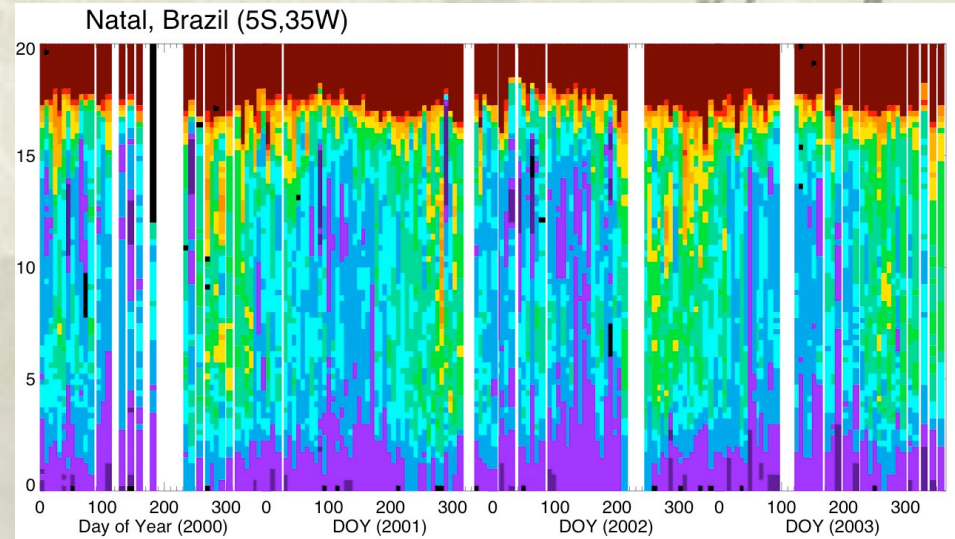
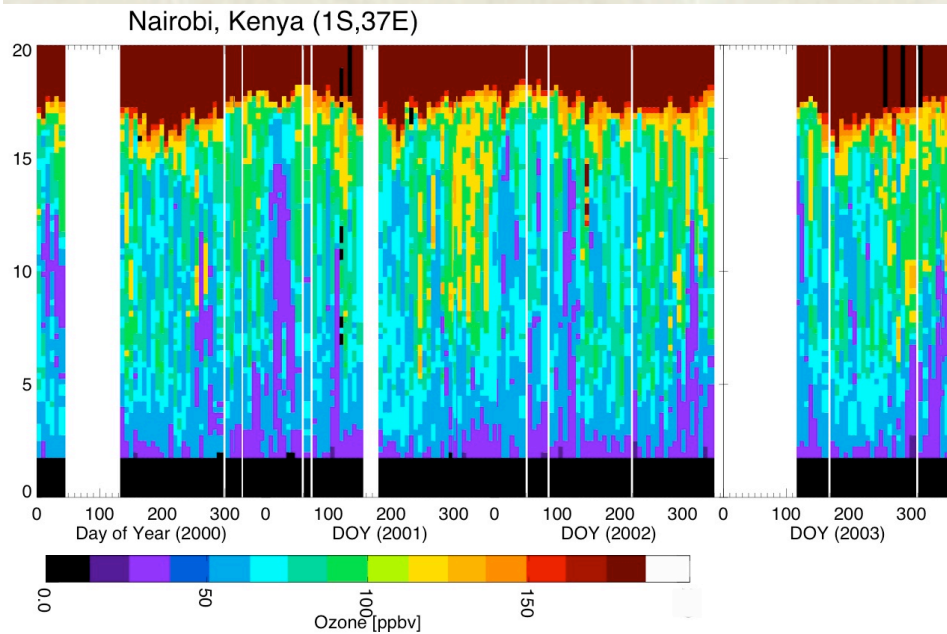
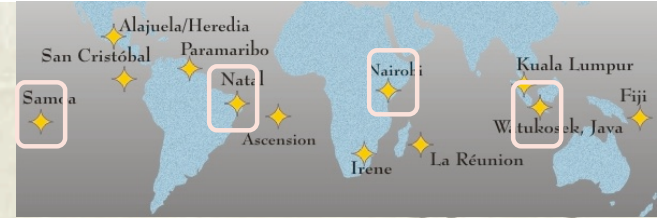


Alajuela, CR 06/04/2008 - 10/08/2008

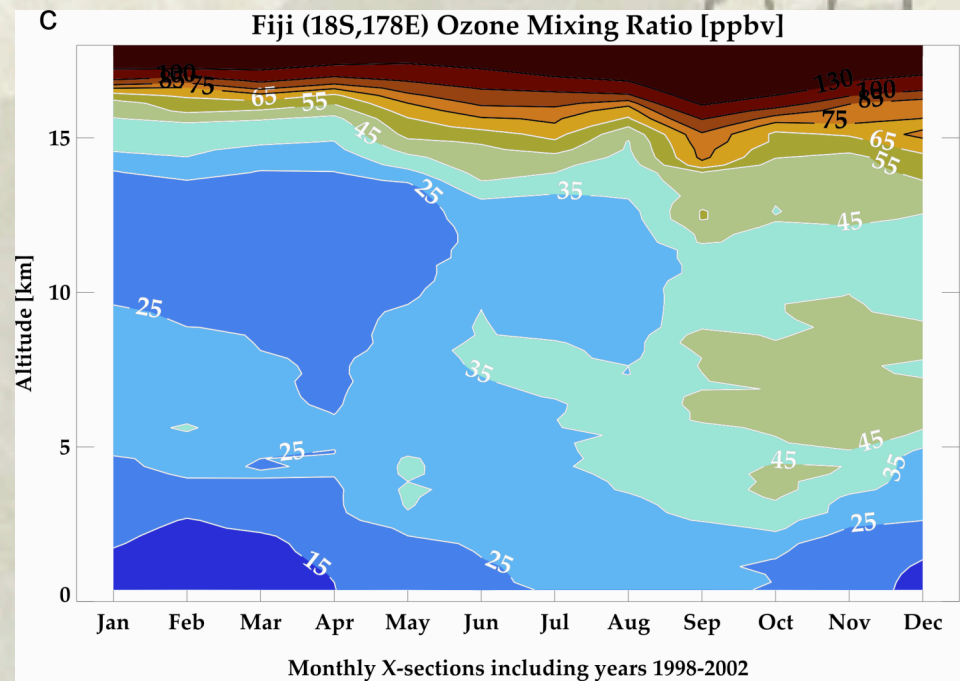
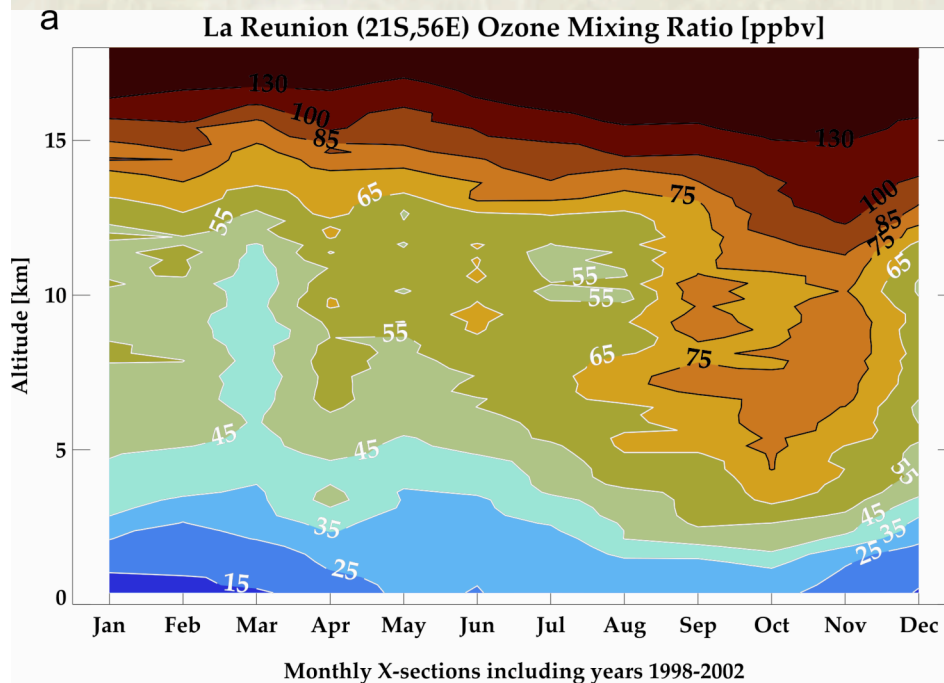
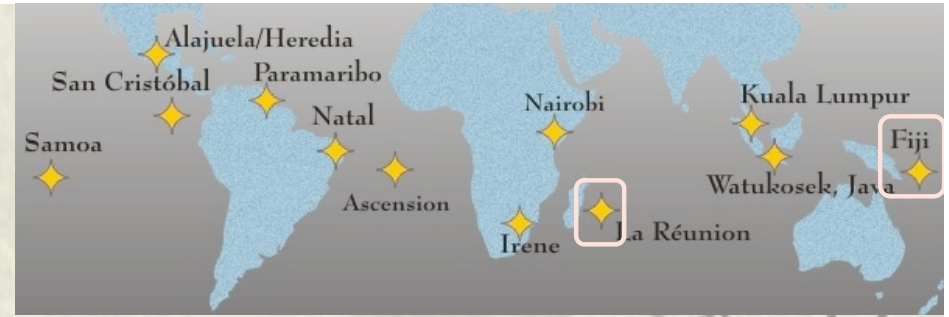




# Station-to-Station, Regional Variability

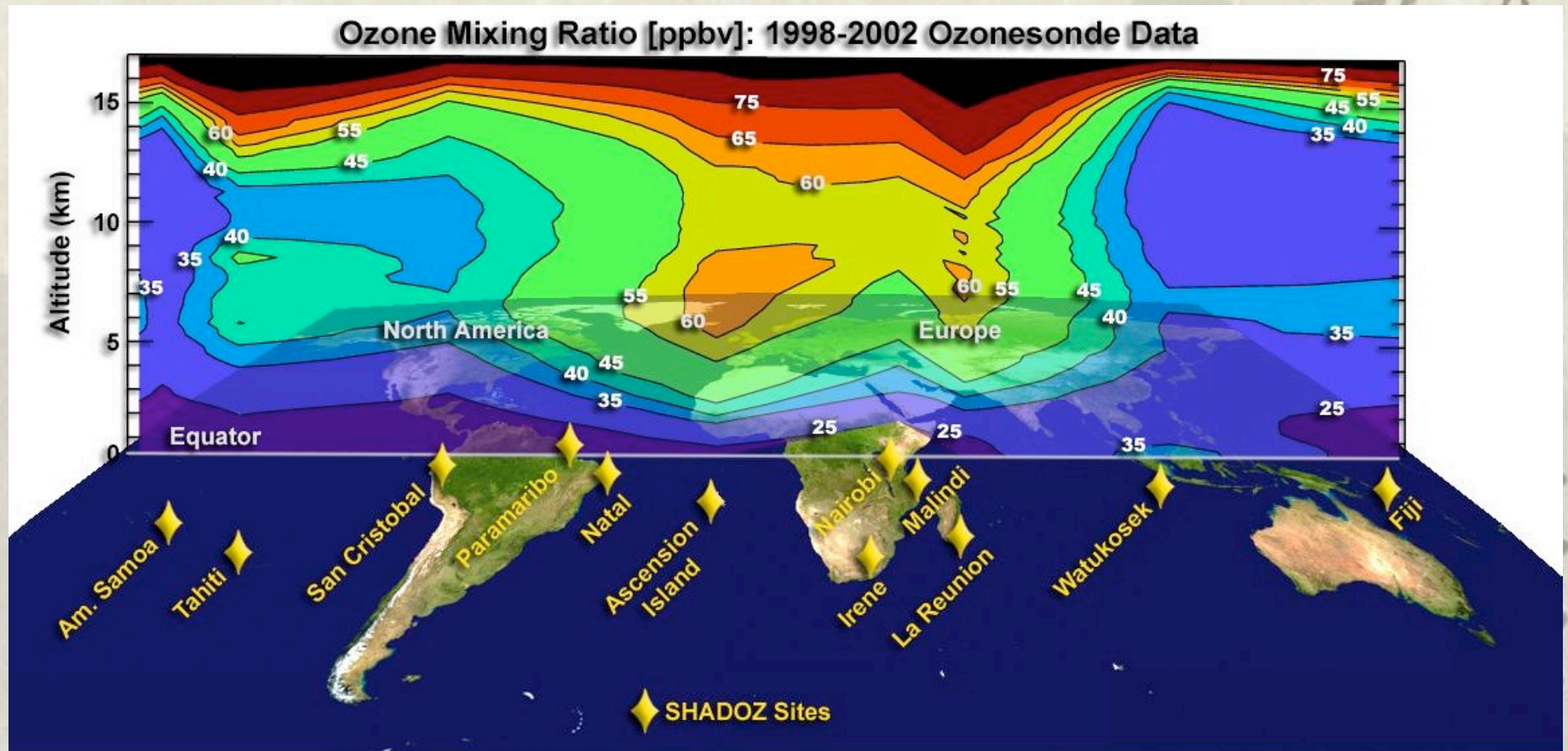
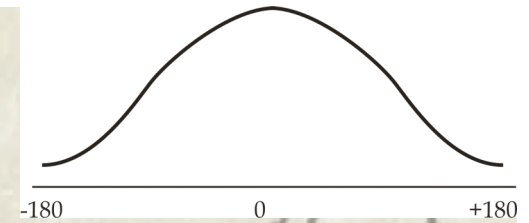


# Seasonal Variability



- ❖ Seasonal cycles in  $O_3$  are due to seasonal changes in upwelling, high altitude convective outflow.

# Tropical Zonal Wave-One

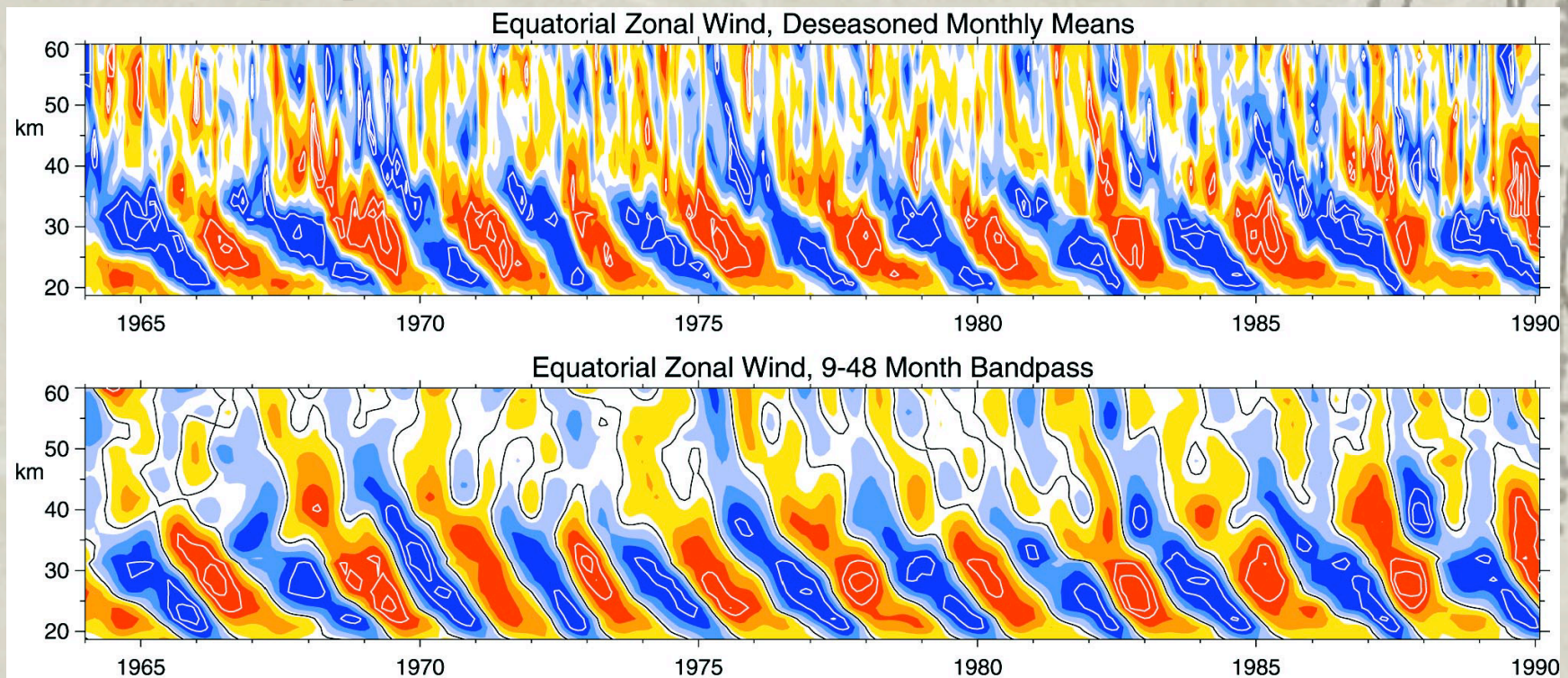


- ❖ Unique zonal view from SHADOZ shows wave present all year
- ❖ A. M. Thompson et al. (2003), *J. Geophys. Res.*, 108, 8241, 2002JD002241.
- ❖ G. Jenkins et al. (2003), *J. Geophys. Res.*, 108, 4745, 2002JD003297.
- ❖ B. Sauvage et al. (2007), *J. Geophys. Res.*, 112, D11309, 2006JD008008.

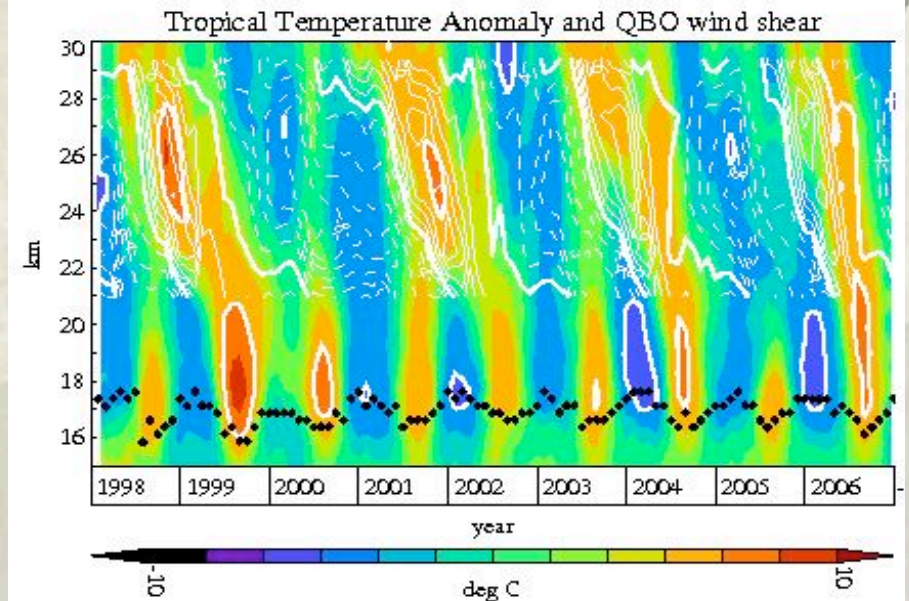
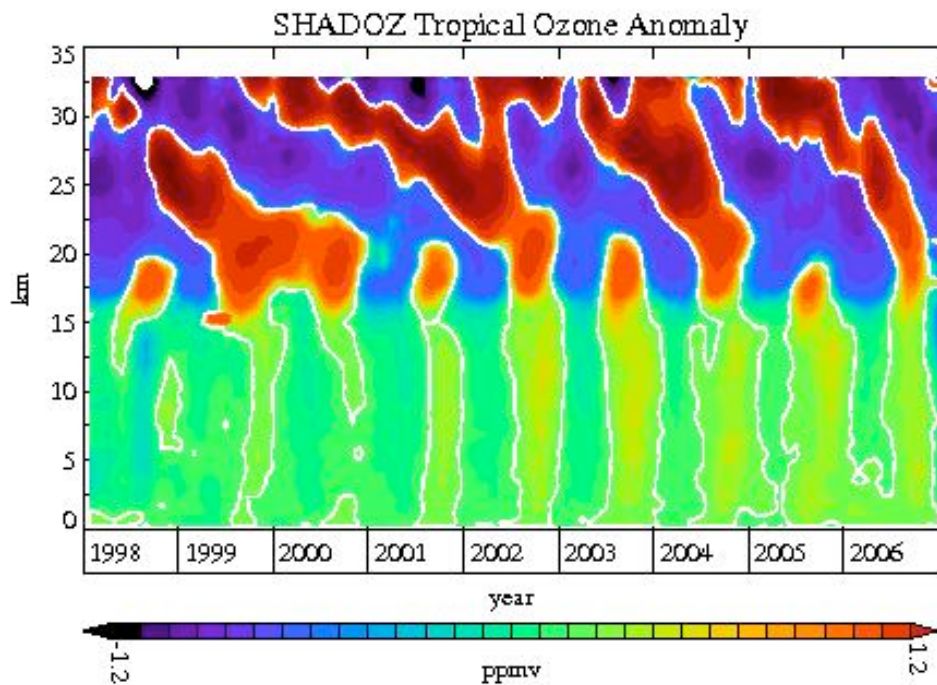
# Quasi-Biennial Oscillation (QBO)

- ❖ Equatorial Feature = Wave-mean interaction = Oscillating easterly and westerly winds.
- ❖ Symmetric about the equator within 10 or so degrees.
- ❖ Periodicity > 2 years
- ❖ Major transport influence on ozone between 20-30km (max ~ 25 km).

1964-1990 [m/s], red=westerlies, blue=easterlies

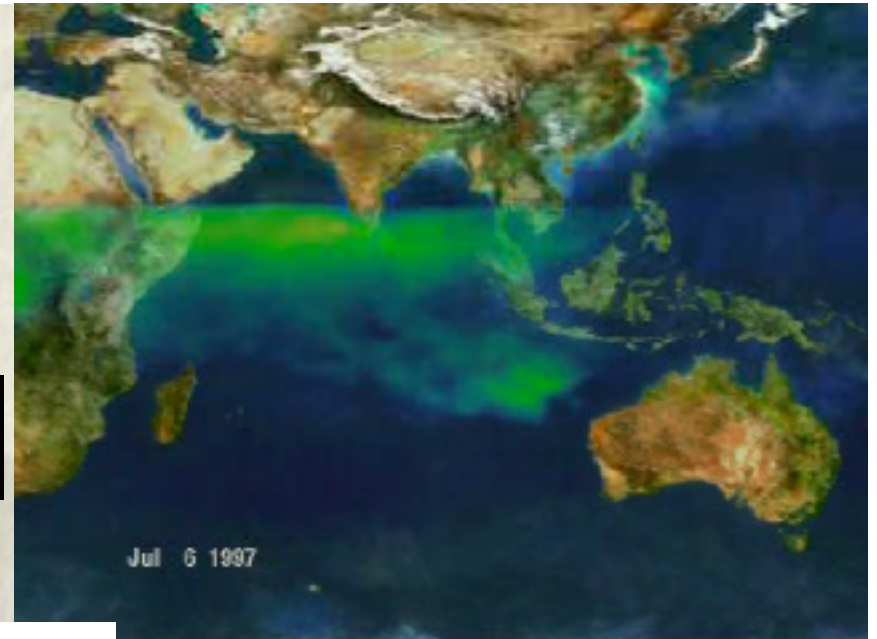
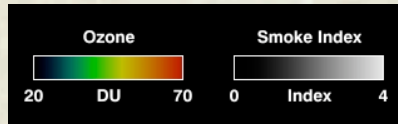


Baldwin et al., *Rev. Geophys.*, 2001

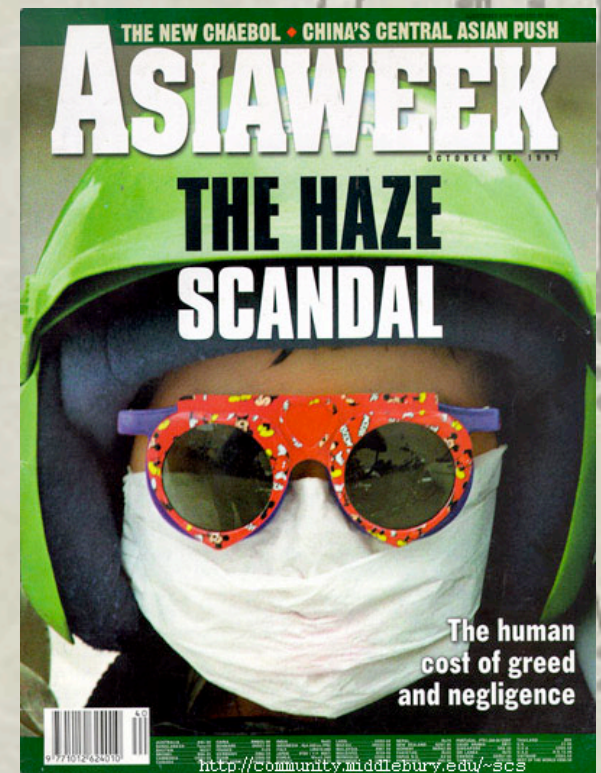
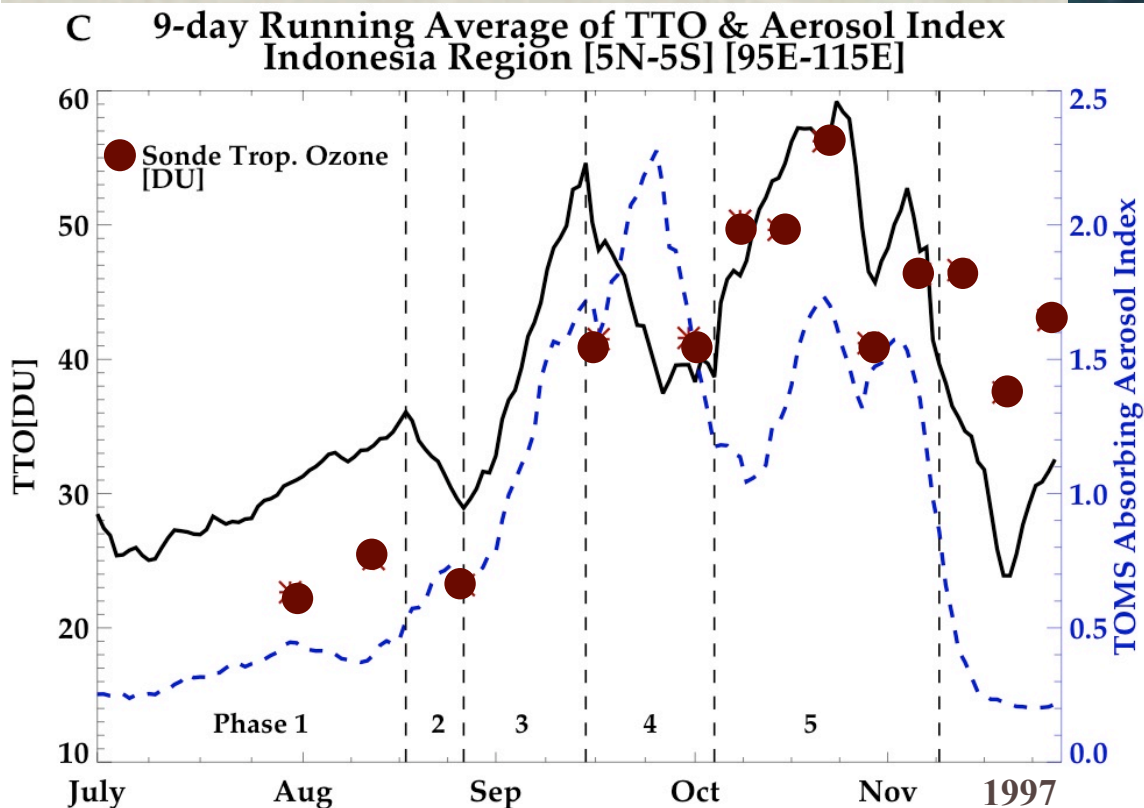


- ❖ 9-year record of ozonesonde data from SHADOZ (1998-2006)
- ❖ 11 stations within +/- 10 degrees of the equator
- ❖ Ozone & Temp. Anomaly = Monthly profiles - 9-year mean reference profile
- ❖ 4 QBO cycles sits atop well-defined annual ozone variations (Brewer-Dobson Circulation).
- ❖ Westerly QBO and BDC ozone phase amplifies the positive ozone perturbation field.
- ❖ Very good agreement between alternating patterns of westerly (easterly) wind shear and positive (negative) ozone and temperature perturbations.
- ❖ Witte et al. (2008) *Atmos. Chem. Phys.*, 8, 3929-3936.

# Tropospheric Smoke and Ozone over Indonesia July - October 1997 Strong El Nino Event



A. M. Thompson et al., *Science*, 291, 2128-2132, 2001



# *SHADOZ in the Aura Era*

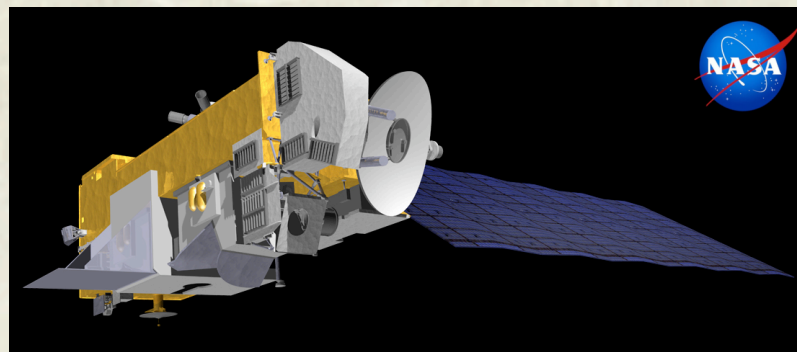
The Aura mission studies the Earth's ozone, air quality and climate. It is designed exclusively to conduct research on the composition, chemistry and dynamics of the Earth's atmosphere.



Aura Launch : July 15, 2004  
Vandenberg Air Force Base, CA



<http://aura.gsfc.nasa.gov>



## Ozone Monitoring Instrument (OMI)

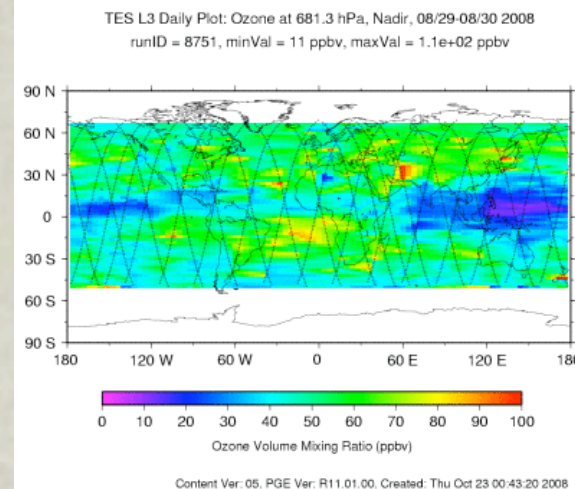
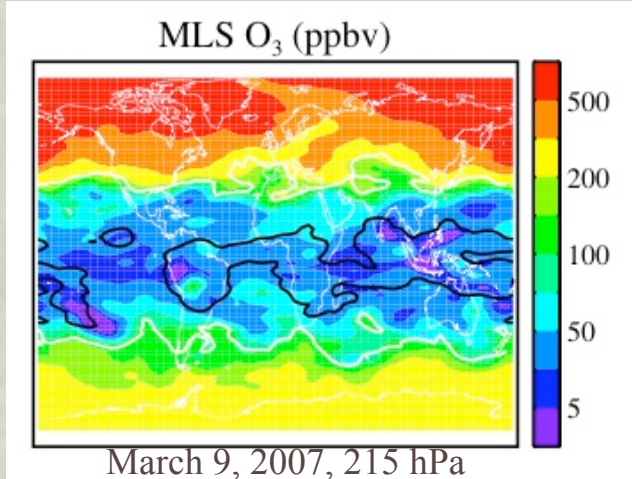
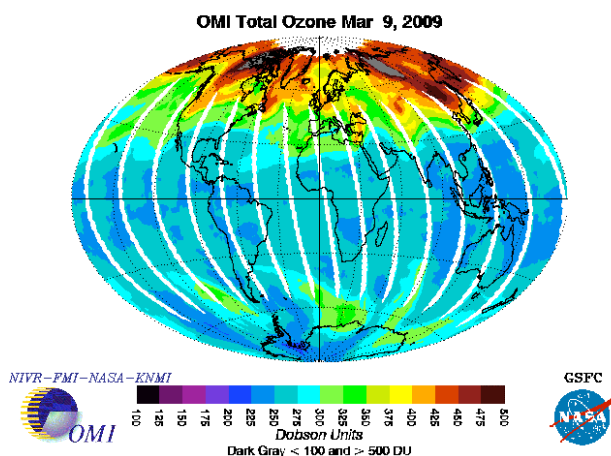
- Measure key air quality components such as column  $O_3$ ,  $NO_2$ ,  $SO_2$ ,  $BrO$ ,  $HCHO$ , and aerosol characteristics
- Daily global coverage
- Capable of mapping pollution products on urban-to-regional scales.

## Microwave Limb Sounder (MLS)

- vertical profiles of atmospheric gases ( $OH$ ,  $O_3$ ,  $H_2O$ ,  $N_2O$ ,  $BrO$ ,  $CO$ ), temperature, pressure, and cloud ice down to 100 hPa.

## Tropospheric Emission Spectrometer (TES)

- Measurements of gradients of many tropospheric species (e.g.  $O_3$ ,  $CO$ ,  $H_2O$ ,  $HNO_3$ ) in order to understand troposphere-stratosphere exchange



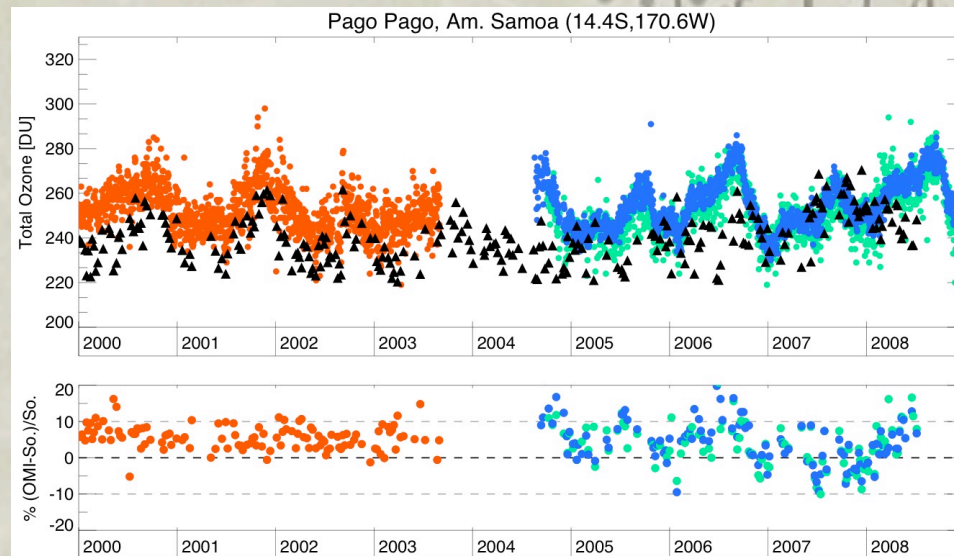
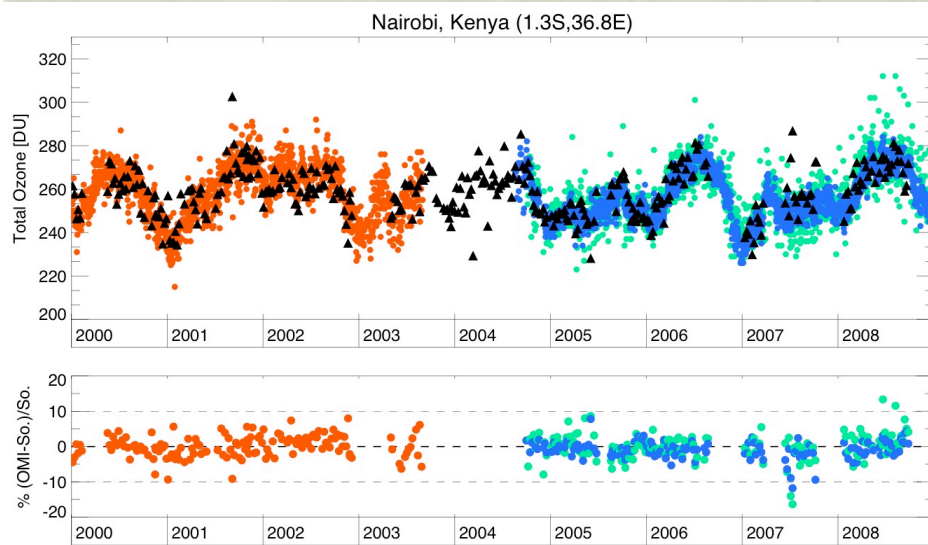
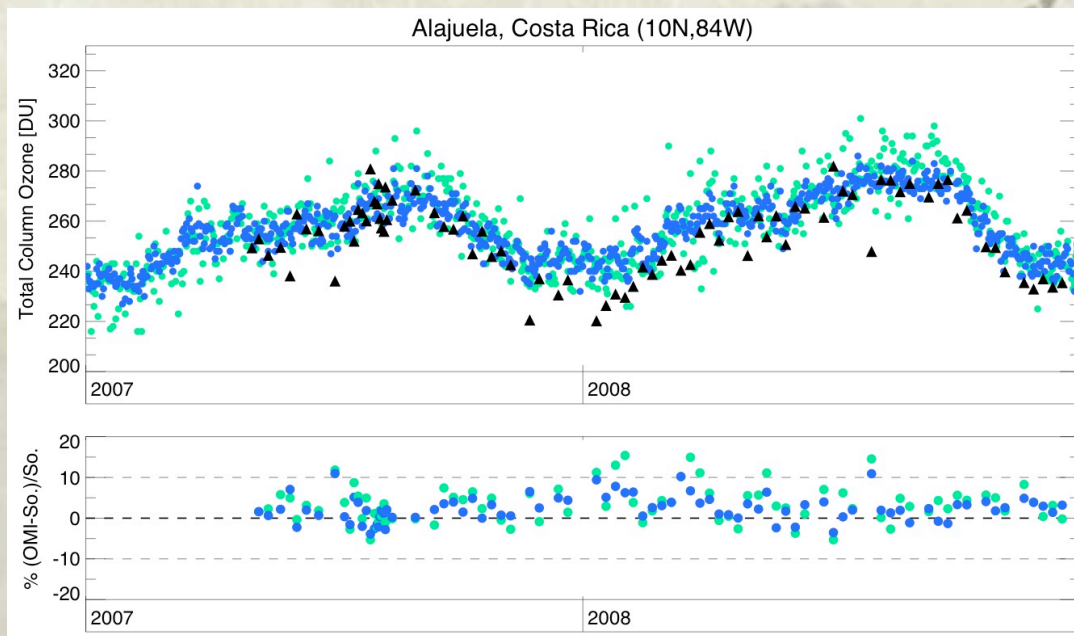
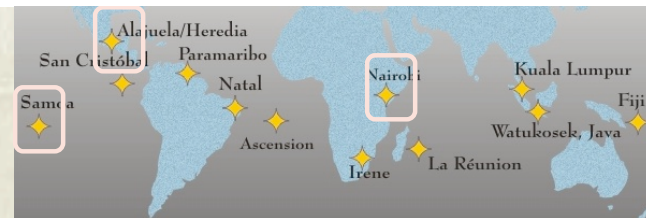
# Sonde-TOMS/OMI Total Column $O_3$ Comparisons

TOMS

OMI-TOMS

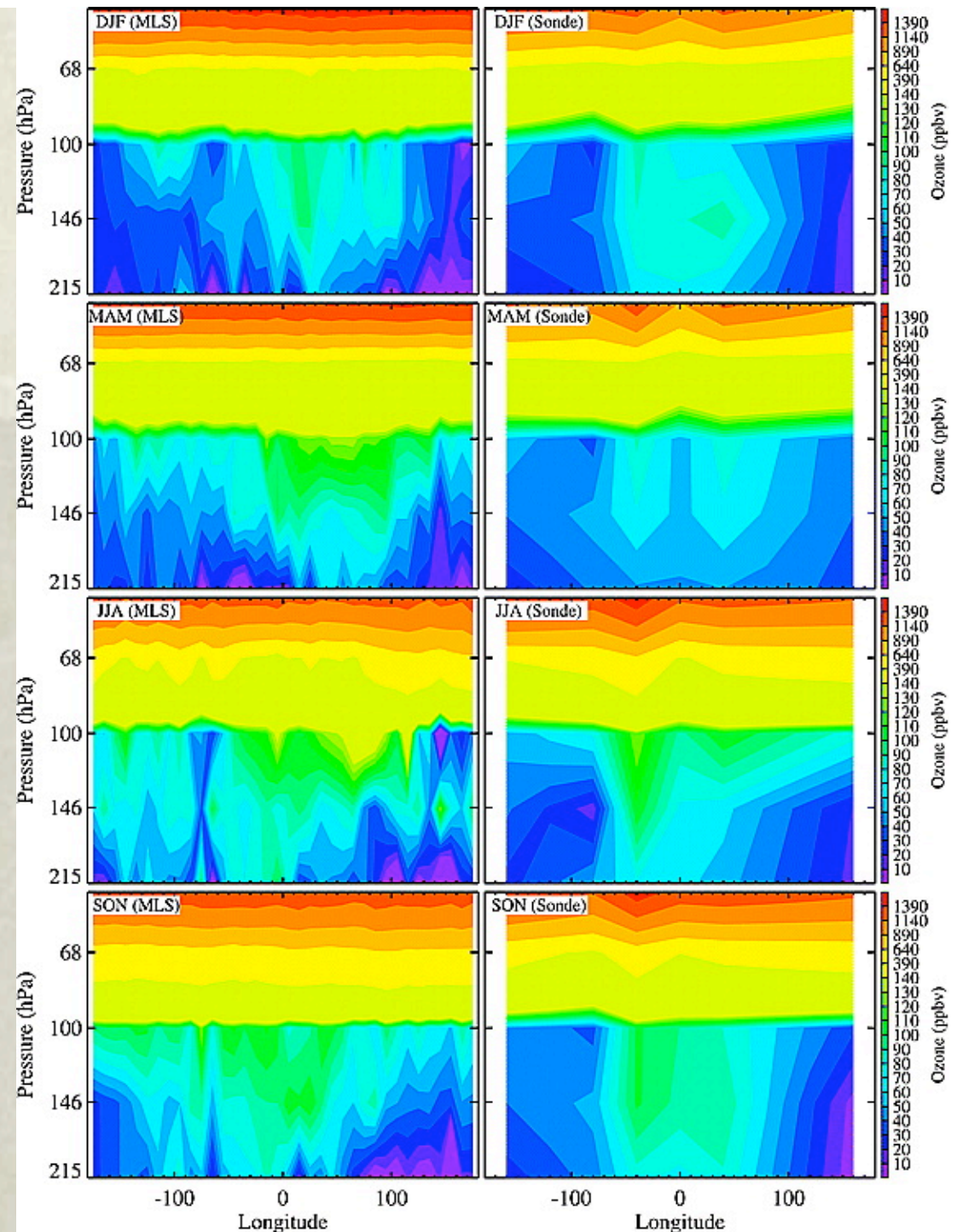
OMI-DOAS

▲ Sonde+LLM Clim.

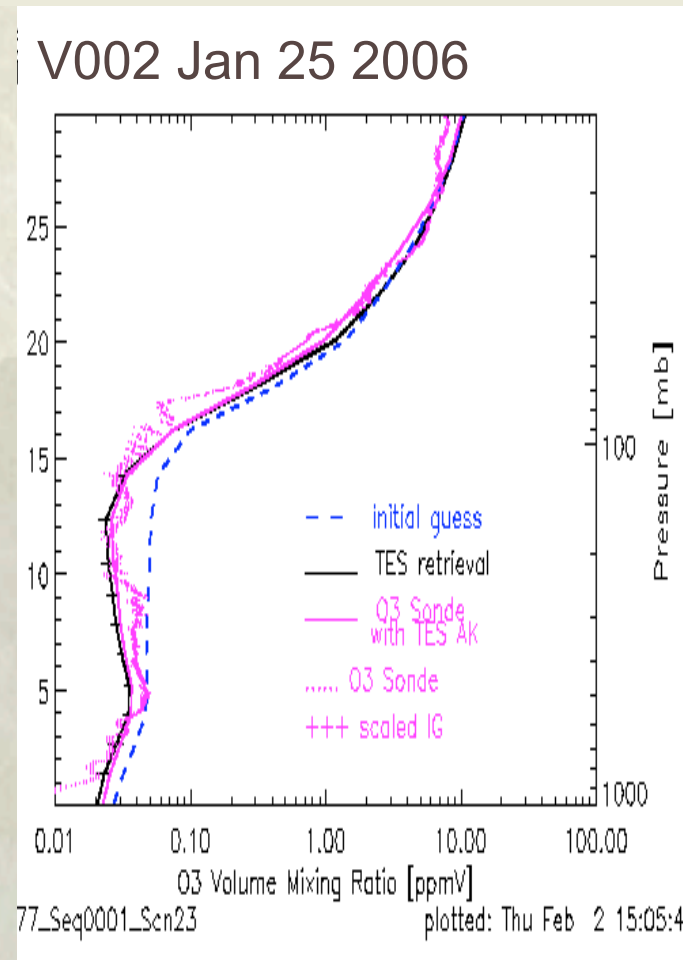
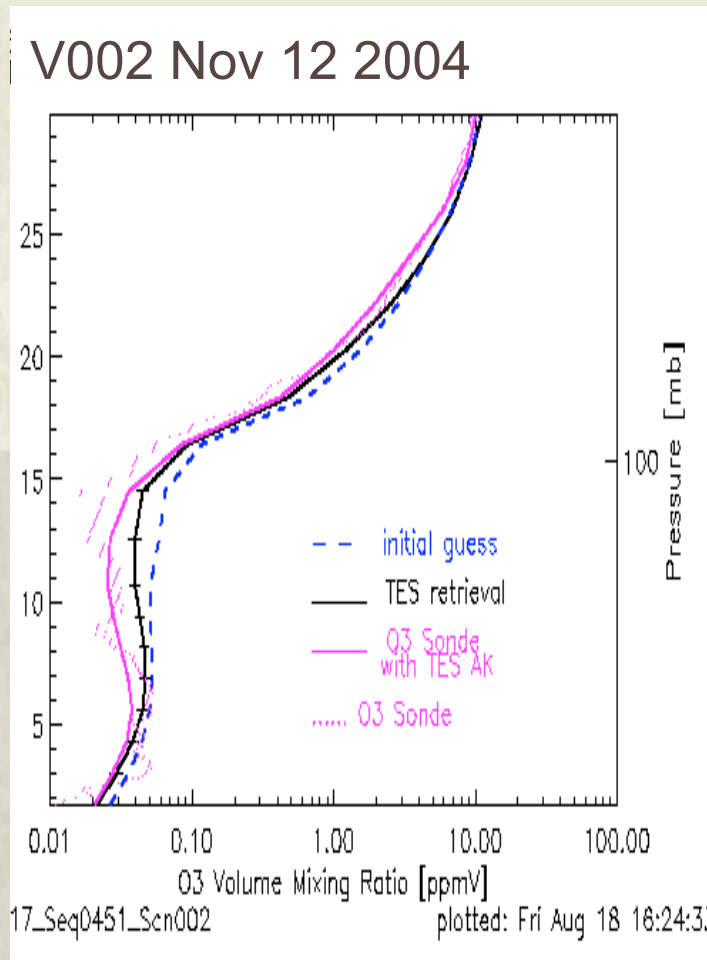


# Sonde-MLS Upper Troposphere $O_3$ profile Comparisons

- ❖ Y. Jiang et al., (2007) Validation of Aura Microwave Limb Sounder Ozone by ozonesonde and lidar measurements, *J. Geophys Res.*, 112, D24S34, 2007JD008776, 2007
- ❖ Used MLS V1.5, SHADOZ 2004-2005 measurements
- ❖ MLS tropical data show the wave one longitudinal pattern in the upper troposphere
- ❖ MLS bias high within 20% or 20 ppbv, on average, in the tropics.



## *San Cristobal, Galapagos Sondes - TES O<sub>3</sub> Profile Comparison*



- ❖ Sonde launches timed for Aura TES overpasses have been extremely useful.
  - Use of ozonesondes in diagnosing TES calibration/retrieval errors.
- ❖ Work done by H. Worden, G. Osterman, R. Herman at JPL



Thank you very much.

